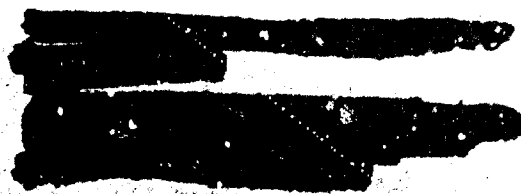


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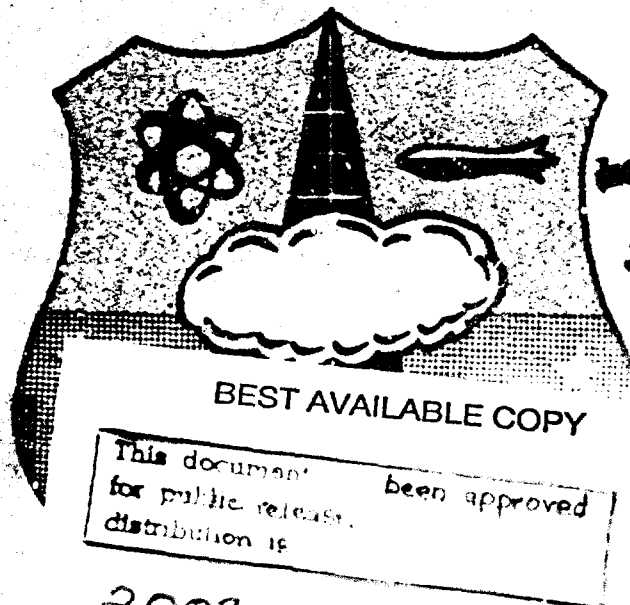
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AIR FORCE SPECIAL WEAPONS CENTER

AIR RESEARCH AND DEVELOPMENT COMMAND

KIRTLAND AIR FORCE BASE, NEW MEXICO



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Volume III

HUMAN FACTORS HANDBOOK

For Design of Protective and Storage
Ground Support Equipment

by

Paul H. Newman
George L. Murphy

AMERICAN INSTITUTE FOR RESEARCH

April 1959

AIR FORCE WEAPONS LABORATORY
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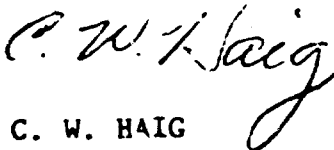
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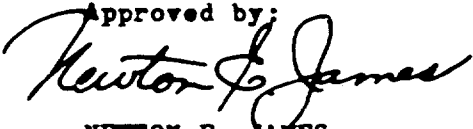
HUMAN FACTORS HANDBOOK
FOR DESIGN OF PROTECTIVE AND STORAGE
GROUND SUPPORT EQUIPMENT

by


Paul H. Lewman
George L. Murphy

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April 1959

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ABSTRACT

This handbook, Volume III in a series of three, has been prepared for designers of Protective and Storage Equipment used to support airborne weapons. Volume I is concerned with Transporting, Positioning, and Lifting Equipment; Volume II, with Testing and Monitoring Equipment. The three volumes are intended as guides for the military or industrial designer who translates an idea into drawings and eventually into actual equipment. They may also be useful to persons preparing specifications for proposed equipment or evaluating such specifications. Each volume is meant to be self-sufficient and for this reason some duplication of material from book to book has been judged necessary.

The chapter headings in Tables of Contents show in general the types of equipment discussed in each handbook. An Index in each book contains page references to aid the user in locating information on specific components. A selected bibliography has also been included in each book, for use if detailed source information is needed beyond that found in the handbook.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



CAREY L. O'BRYAN, JR.
Colonel USAF
Chief of Staff

FOREWORD

The term "human engineering" has been used in recent years to characterize the work of specialists who assist engineers in the design of equipment for human use. Equipment has always been designed for human use, but only with the advent of modern weapon systems has it become apparent that designing for human use implies a need for specialized knowledge of human capabilities and limitations. Whether one considers the term "human engineering" an apt title or a misnomer--and there will be controversy over this for years to come--modern weaponry has underscored the requirement for the inputs this young and growing discipline can make to equipment design. Given the size, complexity, and costs of the weapon systems of today and tomorrow, it has become essential that equipment be so designed as to minimize the likelihood of human error in operation and maintenance, to minimize needs for training and special skills, and to maximize safety and efficiency.

To meet these needs, human engineers have striven to develop "working principles" which embody the best recommendations they can make to engineers responsible for design and development. These "working principles" have come from knowledge of man's mental and physical capacities, from experimental studies of human responses to various types of stimulus conditions, and from observations of man as a functional component in an operational system.

There is a vast amount of literature available to the design engineer who wishes to incorporate human factors principles into his equipment design, but searching this literature constantly would place an unreasonable burden on the engineer. The literature should be summarized for him and made available in a form readily usable and meaningful. That is the purpose of this handbook and its two companion volumes.

Future investigations can be expected to yield more information on human behavior pertinent to the design of ground support equipment, and to confirm or force revision of some working principles which are presently best guesses. Periodic review of these handbooks is recommended so that new information can be incorporated as it becomes available.

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CHAPTER I EQUIPMENT

- A. GENERAL CONSIDERATIONS**
- B. WEIGHT LIMITATIONS**
- C. MAINTENANCE EQUIPMENT**
- D. PROVISIONS FOR INSPECTION
AND MAINTENANCE OF EQUIPMENT**
- E. ACCESSES**
- F. COVERS, CASES, AND HANDLES**
- G. CONNECTIONS AND MOUNTINGS**
- H. SECURING OF SMALL PARTS**
- I. CABLING**
- J. SECURITY CURTAINS AND COVERS**
- K. STORAGE PALLETS, BOLSTERS AND CRADLES**
- L. PROTECTIVE CLOTHING**
- M. PACKING AND SHIPPING CONTAINERS**

A. GENERAL CONSIDERATIONS

1. Design such that tolerances are only as close as necessary.

- a. Tolerances should be sufficient to accommodate various sizes and characteristics of any one type of article.

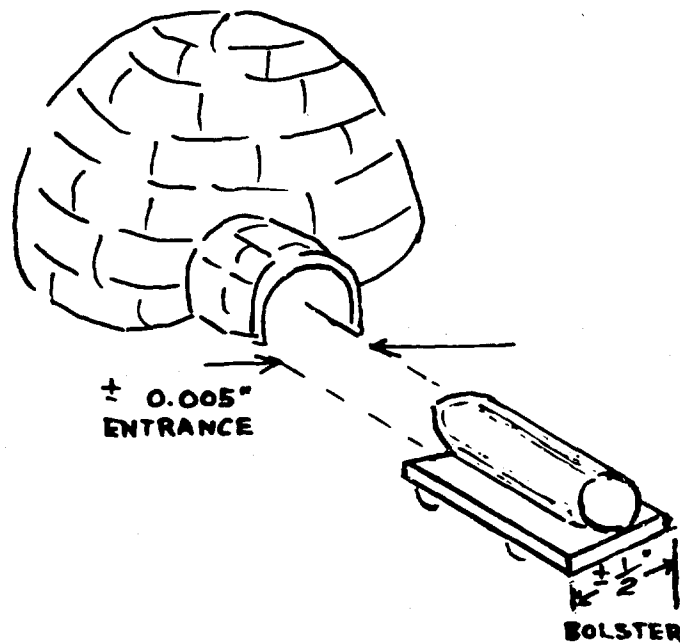


Figure 1 - When bolster tolerance is wide, there is no value to close tolerance of igloo entrance.

2. Design components so they cannot be installed incorrectly.

- a. Components or parts should be designed so that they can only be inserted or attached at the proper location.
 - b. Design components so they can be installed only in the proper way. Use keyed design or tapered alignment pins, for example.
- ### 3. Design equipment to be compatible with the needs of the operator under all environmental conditions expected.
- ### 4. Design equipment to avoid hazard to the operator.
- a. Include "fail-safe" features whenever possible.
 - b. Provide adequate guards for sharp or moving parts.
 - c. Use spark arresters on equipment incorporating internal combustion engines.
 - d. Provide covers to enclose protrusions, rails and corners with which operators may come in contact.
 - e. Insulate all exposed shock sources.



5. Design equipment so that responses made in emergency situations are brief and simple.
 - a. Emergency responses should utilize the force of gravity.
 - b. Do not require precise adjustments to be made in emergencies.
 - c. Make emergency responses unrelated and different from routine responses.

B. WEIGHT LIMITATIONS

1. When units are to be handled by one man, they should be small and weigh no more than 30 pounds.

Provide convenient handles to assist in removal, replacement, or carrying of units weighing more than 10 pounds.

Occasional Movement or Short Distance		Frequent Movement or Long Distance	
TYPE	WEIGHT	TYPE	WEIGHT
I	60 pounds	I	35 pounds
II	20 pounds	II	----- *
III	60 pounds	III	35 pounds
IV	30 pounds each hand	IV	20 pounds each hand
V	35 pounds	V	20 pounds

Figure 2

CARRYING CAPABILITIES FOR PACKAGES OF DIFFERENT SIZES AND SHAPES

* Type II package should not be moved frequently or for long distances regardless of weight.

BEST AVAILABLE COPY

2. Require the operator to lift no higher than 5 feet. See Table 1, below for maximum lifting capability.

Table 1 LIFTING CAPABILITY	
Height of Lift	Lifting Capability (not carrying)
1 foot	142 pounds
2 feet	139 pounds
3 feet	77 pounds
4 feet	55 pounds
5 feet	36 pounds

C. MAINTENANCE EQUIPMENT

STANDS, TABLES, AND LADDERS

1. Provide built-in or auxiliary stands so that units, while being worked on, will not be set on delicate components.
 - a. To prevent overloading, indicate capacity in pounds on stands, tables, ladders, etc.
 - b. Incorporate self-locking, fool-proof devices to prevent accidental or inadvertent collapse or lowering of elevating stands or platforms.
 - c. Design maintenance stands so that they can be used on inclined surfaces up to 15 degrees without danger of tipping when weight of operator and components under maintenance is applied at one side.

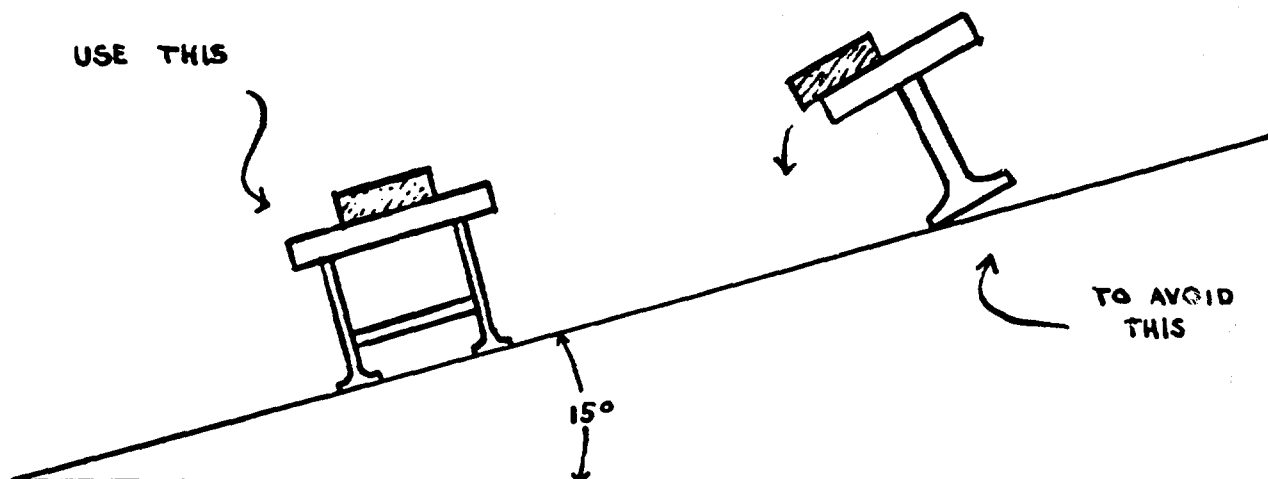


Figure 3



- d. Provide brakes or retractable wheels to prevent movement when maintenance equipment is in use.
 - e. Provide tie-downs for protection against high wind tipping the stands.
 - f. If sharp edges and protrusions cannot be eliminated, insure that they are marked conspicuously.
2. Use non-skid metallic treads, expanded metal flooring, or abrasive coating on walkways, catwalks and all surfaces used for climbing.
- a. On steps and ladders use non-skid design for steps or cover them with abrasive material.
 - b. Design ladders and steps so they may be deiced when necessary by use of hot water or steam.
3. Place hand-grips on platforms, walkways, stairs and around floor openings.
- a. Ordinarily these hand-grips should be of the fixed type.
 - b. Hand-grips, if not fixed, may be folding or telescoping, normally concealed or flush with the surface.

Hand-grips should remain securely folded when not in use. Tools should not be required to move them from the folded position.

TOOLS

4. Design equipment such that special tools and the number of different tools are kept to a minimum.
- a. Design tools to be compatible with the job to be performed.
 - (1) Provide ratchet type tools for working in limited space.
 - (2) Provide speed tools when screws must be rotated through many revolutions.
 - (3) Provide screwdriver with funnel-like shield for making small size screw adjustments. (See Figure 4a)

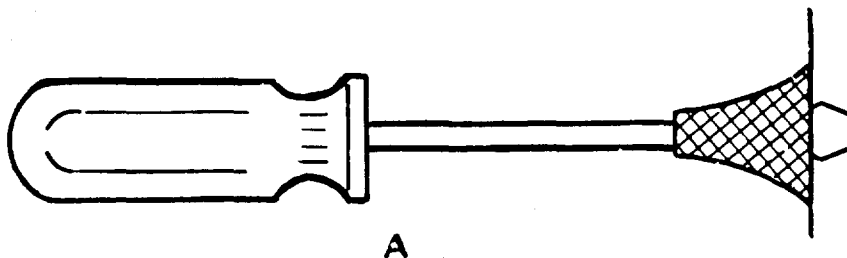
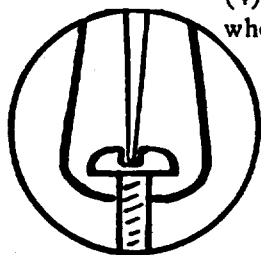


Figure 4 (a)



(4) Provide screwdrivers with clips to hold screws which must be installed where finger clearance is not sufficient. (See Figure 4b)

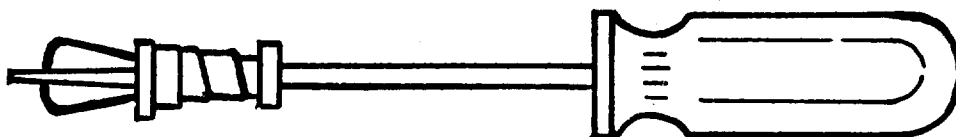


Figure 4 (b)

- b. Avoid metal handles on tools which are to be used in extreme cold or in tropical or desert areas.
- c. Design tools for portability, by keeping size and weight to the minimum required for strength.
- d. Prepare a complete list of tools needed in the maintenance of a piece of equipment for inclusion in pertinent maintenance manuals.

D. PROVISIONS FOR INSPECTION AND MAINTENANCE OF EQUIPMENT

1. Provisions should be made for ready disconnection, removal and replacement of major sub-assemblies or components.

a. Design equipment so that operators using or repairing it may clearly see all the parts with which they are required to work.

(1) Units which require frequent visual inspection should be installed in positions where they can be easily seen without removing panels, covers, and other units.

(2) Units should not be placed behind items which are difficult to remove unless this serves some functional purpose, such as protecting the unit.

(3) Design equipment so structural members do not prevent access to components.

b. Mount units and assemblies so that replacing one unit does not require removal of other units.

c. Provide accesses wherever frequent maintenance operations would otherwise require removing a case or covering, opening a fitting, or dismantling a component.

2. Design equipment so that regularly stocked units are used in its maintenance.

a. Design connections, plugs and mountings so that identical assemblies, sub-assemblies and parts are interchangeable both within and between equipments.

b. Design units to be replaceable with no more than common hand tools.

c. Testing equipment should be stored by type. Outer case should be labeled.

3. Use quick locking dowel pins and other similar devices to facilitate assembly and disassembly of items. (See Figure 5)

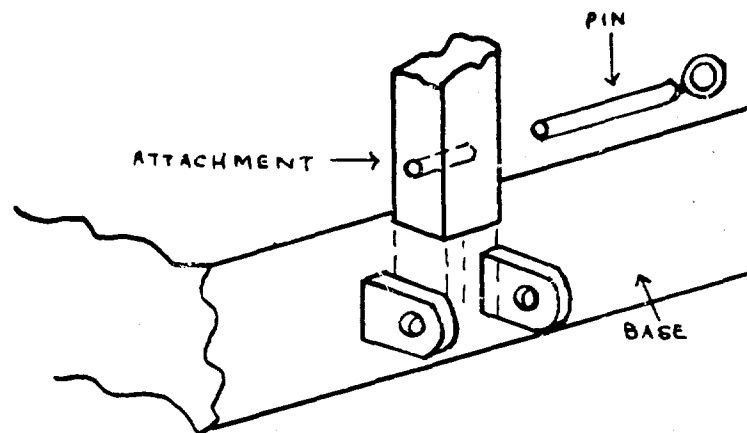


Figure 5

4. Provide inspection covers, zippers in cloth openings, quick fasteners and other measures to facilitate inspections.

Provide sufficient space to use test probes, soldering irons, and other required tools without difficulty. (See Section E, this chapter.)

E. ACCESSES

1. For frequent maintenance operations, design accesses to avoid constant removal of cases or covers, opening of fittings, or dismantling of components.

Table 2 TYPES OF ACCESSES IN ORDER OF PREFERENCE			
	VISUAL INSPECTION ACCESSES	PHYSICAL ACCESS REQUIRING REMOVAL OF COMPONENT OR INSERTION OF TECHNICIAN'S ARM	TOOLS, TEST LEADS AND SERVICE EQUIPMENT ACCESSES
FIRST PREFERENCE	An opening with no cover	Hinged door	Opening with no cover
SECOND PREFERENCE	A plastic window covering	A coverplate with a few large screws	A sliding or hinged door (spring loaded cap)
THIRD PREFERENCE	A break-resistant glass window	—	A quick opening cover plate

2. Provide edges of accesses with internal rubber, fiber, or plastic fillets for personnel protection.

3. Make accesses large enough for easy passage of components, tools and technician's arms and hands, as tabulated below. If technician will be wearing cold weather gear, including gloves or mittens, access dimensions must be increased to allow for such additional clothing.

<p style="text-align: center;">Table 3 MINIMUM ACCESS OPENINGS</p>	
Use (Purpose)	Size
Holding empty hand flat	2¼" x 4½"
Inserting empty hand thru square opening	3½" x 3½"
Holding small pin or tube between thumb and fingers	2" circle
Holding 8" screwdriver with 1" diameter handle	3¾" square hole
Inserting large pin or tube (1½" diameter x 4½" height)	4" circle
Tightening or installing AN connector O.D. 1¾"	4" square hole
Inserting hand held box	Box width plus 1¼"
Reaching in full arm's length to the shoulder	4" height and 19" width
Holding box over 13½" width held between hands on its side to full arm's length	4½" to 5½" greater than box width
Inserting box by handles on front or rear	1" to 1½" clearance both sides
Reaching for depths of 6" to 25" to perform two-handed tasks	4" height and ¼ of depth reach
Inserting component through opening with arms	Component height plus 1", width plus 8"

ACCESS PLACEMENT

4. Place accesses to permit maximum convenience in performing job procedures.

a. Location of access should be dictated by the position of internal components, and the way in which they must be installed.



- b. Place accesses to accommodate the operation a technician will have to perform through the given access.
 - c. Determine which faces of equipment will be accessible in normal installation and place access on one of them.
5. Visibility and accessibility need not be provided through the same access.
- a. Provide at least one access door and one window if the technician must be able to see what he is doing inside the access.

ACCESS COVERINGS

6. Provide convenient means of opening and closing accesses.
- a. Use a hinged door in preference to a cover plate secured with screws.
Access doors should open downward to eliminate necessity of holding open.
 - b. Where lack of available space for opening access prevents use of hinged door, cover plates may be used.
For attaching cover plates use:
 - 1. Fasteners requiring no tools and only a fraction of a turn or snap action to operate.
 - 2. Captive fasteners for one hand operation to avoid loss of fasteners.
 - 3. Large enough operating surfaces on thumb operated quick disconnect access fasteners to eliminate physical injuries.
 - 4. Screws, when access covering must withstand stress (keeping the number of screws at a minimum).

ACCESS LABELING

7. Have each access uniquely labeled with a number, letter, or other symbol designation to allow clear reference in job instructions.
- a. Label each access with the nomenclature for items accessible through it.
 - b. Label each access with nomenclature of auxiliary equipment to be used at it.

F. COVERS, CASES, AND HANDLES

1. Design covers on protective and storage equipment for rapid and safe removal and replacement.
- a. In cover design, use rounded corners and edges for safety.
 - b. Use hinged and tongue-and-slot catches to minimize the number of fasteners needed.
 - c. Provide adequate handles on covers and cases to facilitate removal from unit.
2. Make cases that can be lifted off units rather than units lifted out of cases. (See Fig. 6)

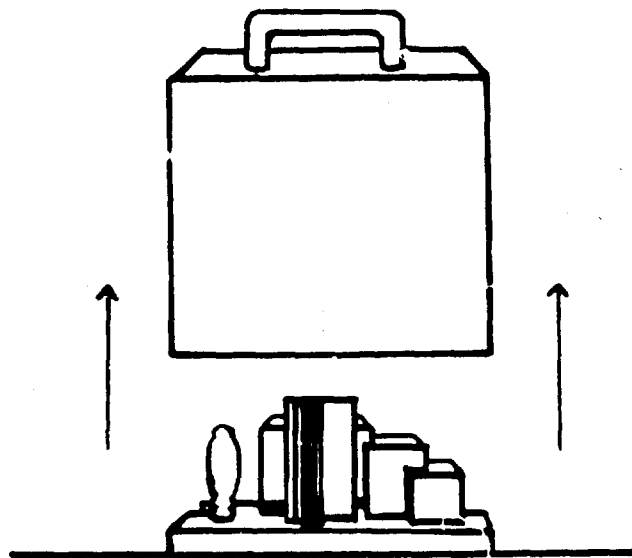


Figure 6

3. Provide adequate handles on all units.

- a. Grips on outer cases must be strong enough to bear the weight of equipment.

Provide handles on small, light units which would otherwise be difficult to grasp, remove, or hold.

- b. Locate grips so that they are at the top of equipment when it is being carried.

Place handles above the center of gravity.

Inside dimensions of carrying handles should be a minimum of $4\frac{1}{2}$ x 2 inches.

Increase dimensions at least $\frac{1}{2}$ " for both length and depth when the operator's hand will be gloved.

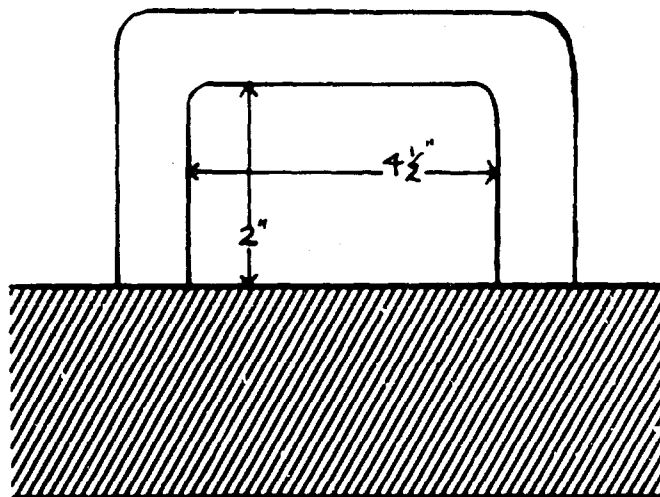


Figure 7

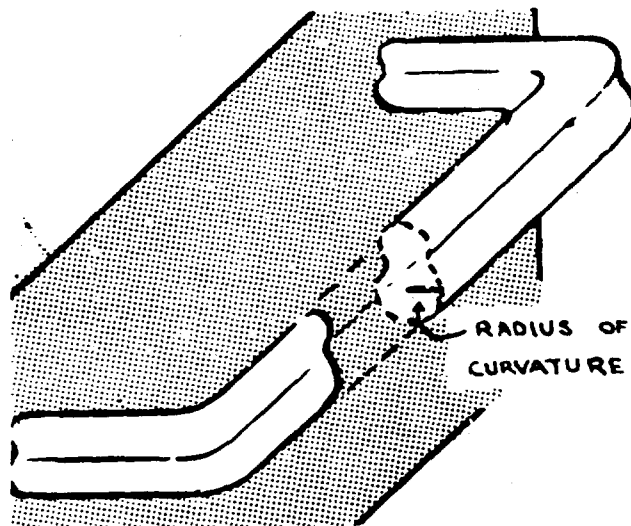


Figure 8

4. Avoid sharp or thin edges on grips.

a. Fingers grasp best on handle diameters from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch.

(1) 10-15 pound packages must have handles or gripping edges with radii of curvature at least $\frac{1}{8}$ ".

(2) 15-20 pound packages must have handles or gripping edges with radii of curvature at least $\frac{1}{4}$ ".

(3) Packages over 20 pounds must have handles or gripping edges with radii of curvature at least $\frac{3}{8}$ ".

5. Gripping efficiency is best if fingers can curl around handle or edge to an angle of 90 degrees or better. (See Figure 9).

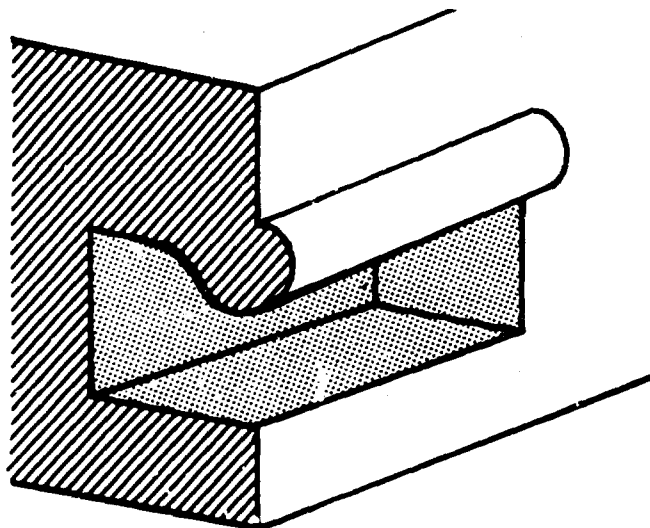


Figure 9

G. CONNECTIONS AND MOUNTINGS

1. Design protective and storage equipments for easy connection and disconnection from each other, basic chassis and housing in which they are installed.

- a. Design units with plug-in instead of solder connections.
- b. Provide fasteners on the side of the units facing free work space.
- c. Label all connection points.
- d. Use connectors requiring no tools (or common hand tools) operating with a fraction of a turn or a quick snap action.
- e. Design fasteners for assemblies and sub-assemblies so that they fasten or unfasten in a maximum of one complete turn.

Provide fasteners which can be operated with the bare hand or at most a common hand tool, and do not require safety wiring.

2. Provide slide-out racks and hoists to aid in handling heavy units.

- a. Use racks with limit stops to prevent dropping equipment.

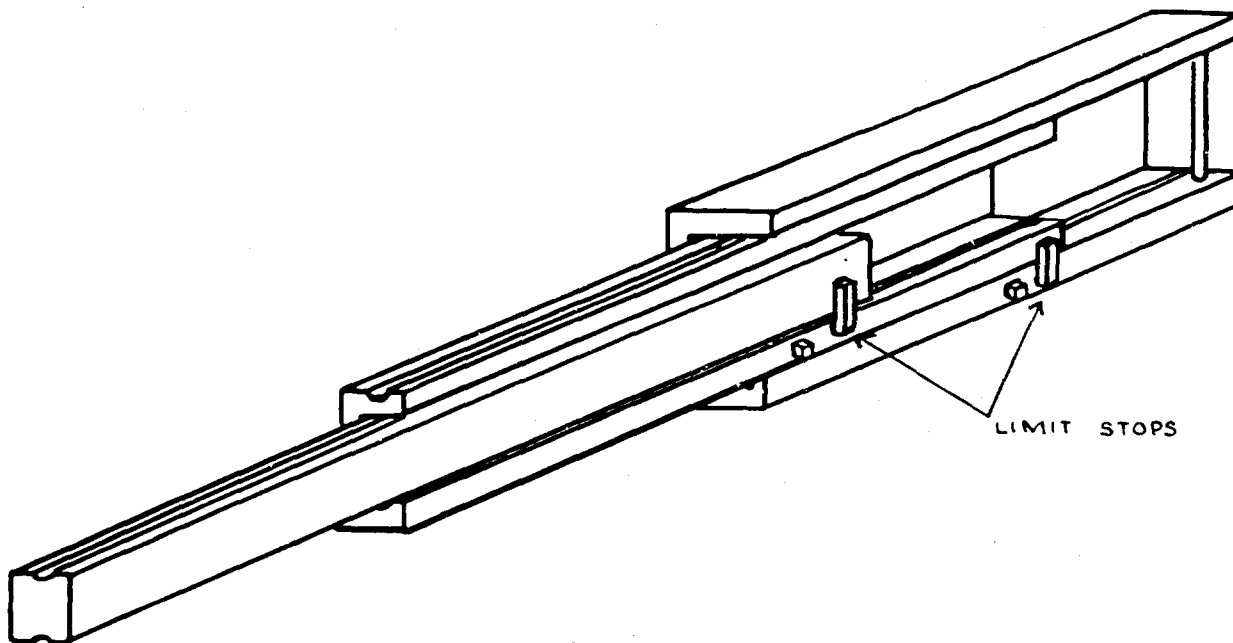


Figure 10

3. For ease in unit connections, provide guides and guide pins for alignment of units on mountings.
4. Design units so that bolts, cables and hoses are easily disconnected for ease in handling units after removal.
5. Keep the number of different sizes and types of screws and connectors used on equipment to a minimum.

6. For ease in unit connections, use a minimum number of mounting screws.

- a. Mounting screws should be a bright color to differentiate them from other screws.
- b. Make mounting bolts semi-permanently captive when there is a possibility of inadvertent misplacement of removed bolts.

7. Keep the number of turns required to tighten or loosen mounting bolts to a minimum.

8. For bolts requiring high torques, use external grip head bolts.

Use combination head bolts with deep internal slot arrangement and hex head for mounting bolts. This will facilitate removal of jammed mounting bolts.

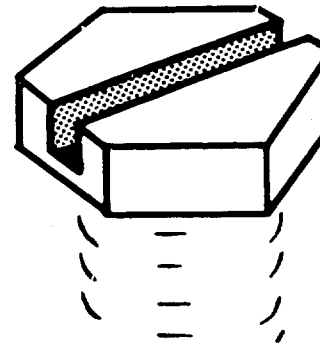


Figure 11

H. SECURING OF SMALL PARTS

Parts which may cause a hazardous condition by working loose in service should be made secure by the use of lock washers or other restraining measures.

Use captive bolts or nuts in situations where there is the possibility of dropping these small items into the equipment.

Attach small removable parts (pins, caps, and covers) to main body of equipment by small link chains or other suitable means to prevent their loss.

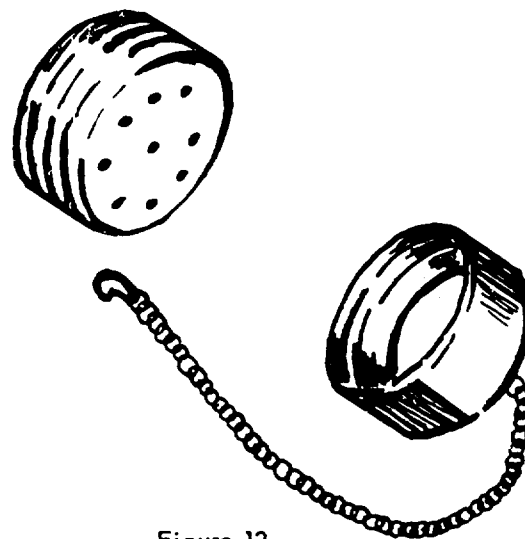


Figure 12

I. CABLING

1. To keep cables out of the way of maintenance operations as well as to prevent them from chafing against metal surfaces, secure them to the chassis or mounting plate by cable clamps. (See Fig. 13)

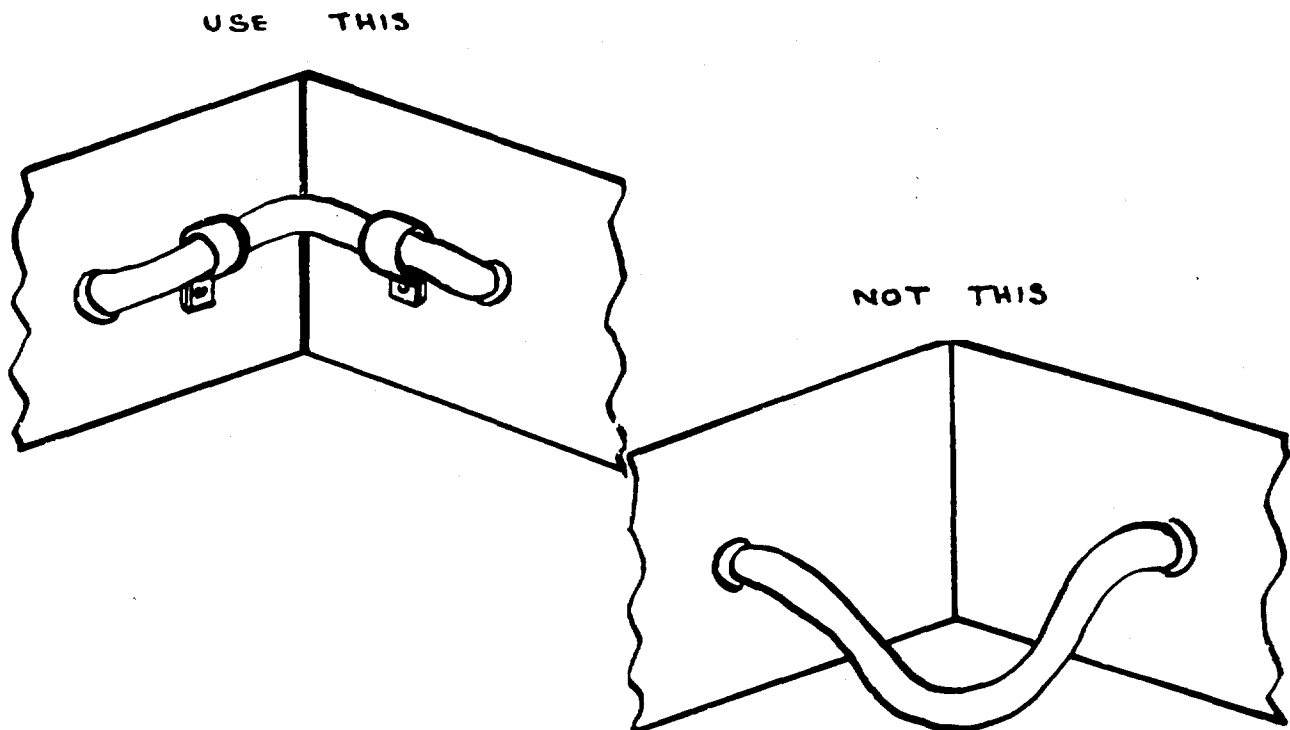


Figure 13

- a. Route cables in such a way that they cannot be pinched by doors or lids, walked on, or used for hand holds.
 - b. Make cables accessible for inspection, removal, replacement, and repair.
2. Place cable junction boxes in an accessible place if trouble-shooting procedures require their use.

J. SECURITY CURTAINS AND COVERS

1. Provide sufficient work space under bomb bays to insure unhampered performance of activities.
 - a. Use hooks to attach the security curtain to the outer edges of the bomb bay doors, rather than to the edges of the bomb bay itself.
 - b. When it is required that a detachable probe be placed through the security cover to aid in aligning and positioning the weapon under the aircraft, provide a slit or other means in the security cover to allow for placement of the probe.
2. Design security curtain and frame fastening devices for rapid attachment.
 - a. Use quick release fastening devices rather than turnbuckles.
 - b. Use hook-and-loop assemblies rather than clevis-lug-pin assemblies.

c. Use thumb-slide security attachment hooks in preference to snap fasteners for attaching security curtains to the frame or aircraft. (See Fig. 14)

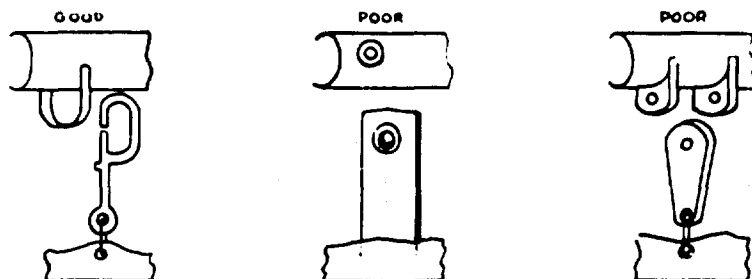


Figure 14

3. To prevent their loss, permanently fasten security curtain attachment hooks to the curtain or frame.

K. STORAGE PALLETS, BOLSTERS AND CRADLES

1. Provide bumper guards on projecting edges of cradles and bolsters.

Use rubber or other suitable material to cover protrusions, rails and corners with which operators may come in contact.

2. Label all lift or hoist attaching points on bolsters and cradles.

3. Storage pallets should be designed so that they can be lifted by fork-lift trucks from all four sides. (See Fig. 15)

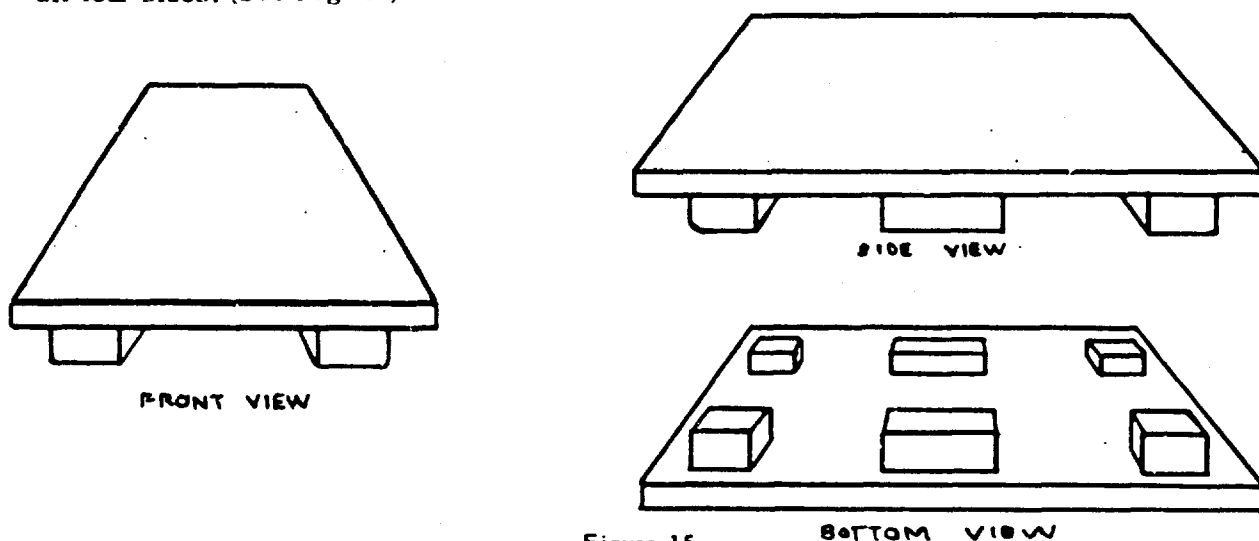


Figure 15

Design pallets so that skids are at least 3" high. This clearance under pallet will prevent accidental damage to equipment.

4. Use pallets for storage of drums, pipe and other cylindrical or spherical materials to facilitate handling of such materials in storage areas.

-
5. Use storage pallets in preference to permanently fixed storage facilities, when the weapon cannot be stored on a transporting vehicle.

When a weapon is stored on a pallet rather than on shelving, transfer time is lessened.

L. PROTECTIVE CLOTHING

1. Protective clothing should be provided whenever toxic, corrosive or dangerous substances may come in contact with personnel.
2. Design protective clothing so that it can be worn without serious discomfort under the actual conditions of work; otherwise worker may discard it. Comfort is an important consideration.

- a. Thickness, rather than weight, determines the protective quality of clothing. However, protective clothing should be no more than 1 inch thick.

Above a certain point, adding more clothing results in decrease in performance.

- b. Arctic clothing should be designed to be wind-proof but permeable to water vapor.
3. Protective clothing should be built up in layers to provide air space.
 4. Do not use mid-thigh cargo pockets for carrying objects. (7½ pounds per thigh leads to an energy expenditure equivalent to carrying 45 pounds on the back.)
 5. Specify gloves in preference to mittens when the operator will manipulate controls.
 - a. Make gloves snug when the covered hand will use toggle switches, push buttons, levers, or knobs.

M. PACKING AND SHIPPING CONTAINERS

1. Size and weight of equipment packaging has direct effect on movability.
 - a. For one-man handling, equipment packages should weigh less than 35 pounds.
 - b. For two-man handling, equipment packages should weigh less than 100 pounds.
 - c. Package width should be no more than 18 inches for one-man handling.
 - d. Shipping containers weighing more than 100 pounds should have wheels or casters.
 - e. For packaging of equipment, locate the center of gravity at the bottom center of the package.
2. Portable equipment should be rectangular in shape for convenient storage.
3. Label all packing and shipping containers to indicate contents.
4. Label all packing and shipping containers to indicate top and bottom of package.
5. Lids on test equipment packages should:
 - a. Be permanently attached.

- b. Have storage space for Technical Orders.
c. Contain display tables and instruction lists.
d. Be easy to open and close.
6. Use a tab (not less than 1½ inches) in preference to a key for opening metal packing containers under arctic conditions.

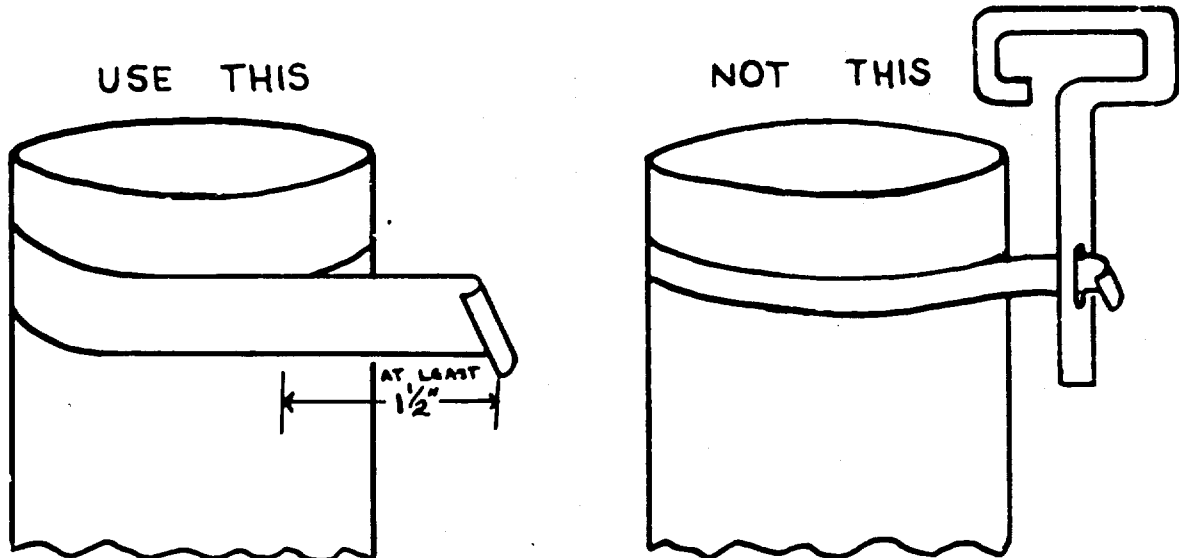


Figure 16

7. Handles on the outside of packages should be recessed or hinged so they do not take up excessive storage space.

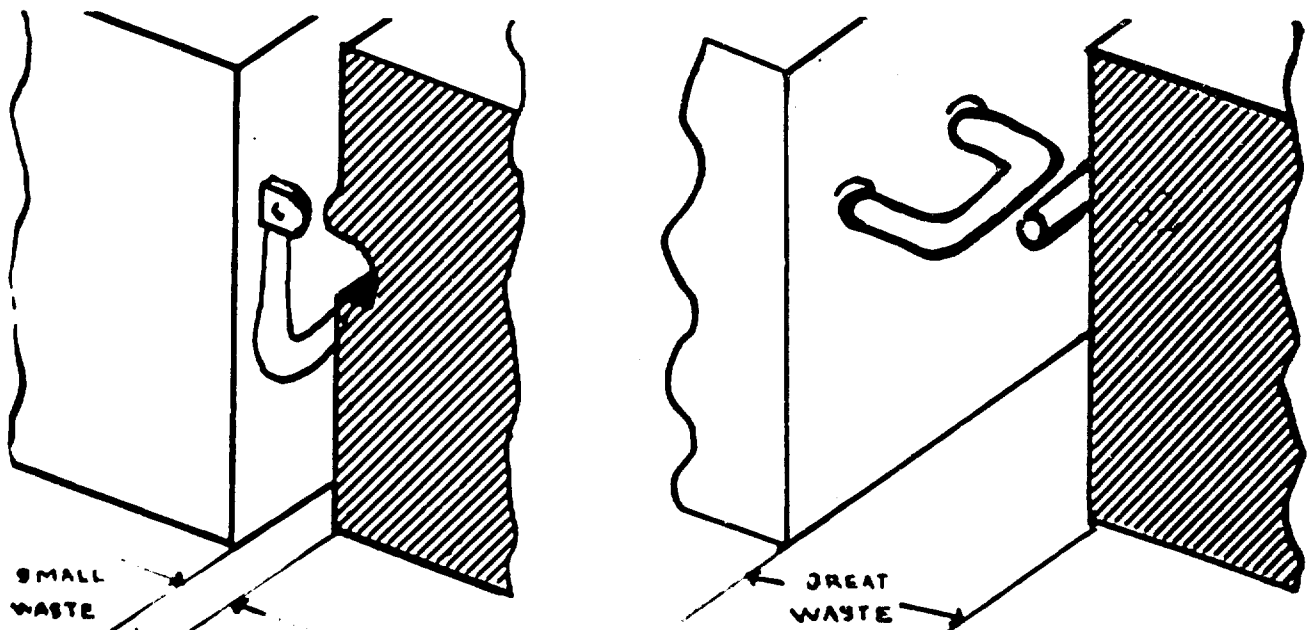


Figure 17

8. Grips should be located towards the top of the can.

- a. Grips should be not less than $4\frac{1}{2}$ inches wide.
- b. Finger clearance between package and grip should be not less than 2 inches.
- c. Provide two large (at least 9 x 2 inches) or four standard grips for two-man handling.
- d. Avoid sharp or thin edges in grips.



CHAPTER II

WARNINGS

- A. AUDITORY WARNINGS
- B. VISUAL WARNINGS
- C. COLOR CODING OF WARNINGS

Warnings are necessary to alert personnel to unusual happenings. For example, when a weapon is stored under controlled temperature or humidity conditions, it is important that personnel be alerted to changes in the temperature or humidity of the storage igloo. Warnings are also valuable to lubricating and painting personnel to alert them to malfunctioning of equipment or to indicate exhaustion of material.



A. AUDITORY WARNINGS

1. Use auditory presentation for warning or alerting the operator under conditions of reduced operator attention.

- a. When a process must be monitored continuously, use auditory presentation.
- b. Use auditory presentation for an alarm, when a signal must be given at an unexpected time in a long continuous watch.
- c. Make loud auditory signals supplement tel-lights for displays which are not constantly watched when it is important that changes in their indication be noted immediately.

2. Auditory signals should be different enough from background noises that they can be easily identified.

a. Design auditory warning system so that:

- (1) It is easily detectable.
- (2) It holds attention.
- (3) It can be quickly and accurately identified.
- (4) Its meaning will always be remembered.

b. Make the initial sound in a warning system as brief as possible while still maintaining the criteria of being detectable, attention-demanding, and discriminating.

c. Make auditory signals easily distinguishable above ambient noise by use of undulating or warbling tones.

For auditory warning make the sound at least 20 decibels above threshold.

d. Do not use continuous high-pitched tones as a warning system.

Avoid sounds above 2000 cycles per second for use as signals.

AUDITORY AND VISUAL WARNINGS

3. Use auditory and visual senses simultaneously for emergency warnings when there is a possibility that one of the senses might be overloaded.

Use auditory and visual presentation simultaneously where great redundancy is desirable.

4. A combined visual and auditory presentation of material leads to more efficient comprehension than the presentation of either auditory or visual material alone.

B. VISUAL WARNINGS

1. Visual presentation should be used for warnings when:

- a. Auditory presentation is not practicable.
- b. Ambient noise prevents the recognition of auditory signals.
- c. The warning must be continuously present.
- d. More than one warning might be presented at the same time.

2. Use a lamp rather than a meter if, for example, all that is needed for a particular circuit is the knowledge that current, resistance, or voltage in question is at a certain threshold or degree of amplitude.

- a. Warning lamps should be within 30 degrees of the normal line of vision.

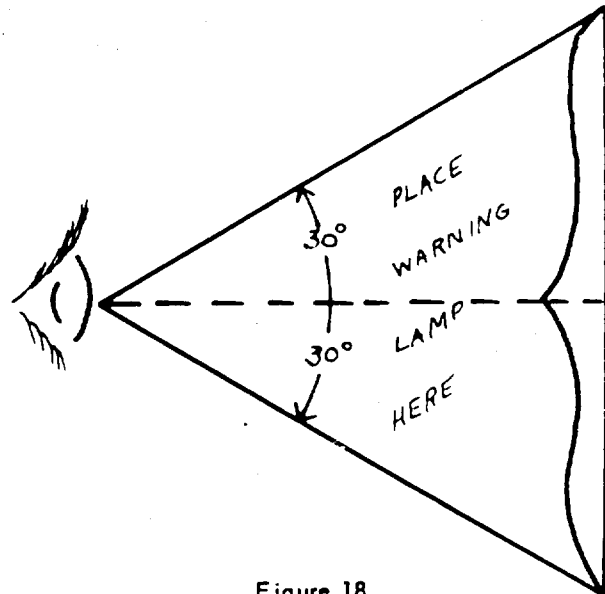


Figure 18

- b. Place the light near the control to be manipulated whenever possible. The lights must, however, be placed where they will be seen immediately.

c. Lights should be clearly labeled, the labels adequately illuminated and the wording of the labels clearly indicating what should be done.

- d. Lights which must attract immediate attention should be at least twice as bright as the background.

3. Pilot and warning lights should be frosted or otherwise treated to minimize the possibility of extraneous reflected light creating the illusion that a light is "on" when actually it is "off."

Use bulb brightness plainly visible in daylight, but not blinding under minimum lighting conditions anticipated.

4. When lights are used as warnings, design their circuits so that the bulbs are fail-safe. If a bulb burns out a warning should still be presented.

5. When lights are used to indicate danger of unusual occurrence, they should flash intermittently. The flash rate should be 3 to 5 cycles per second with the "on" time approximately equal to but not greater than "off" time.



The most effective warning is two lights which flash "on" and "off," alternating like a railroad signal, giving the visual effect of apparent movement.

6. A discussion of human factors considerations pertaining to printed warnings is contained in Chapter 3, Labels and Instructions.

C. COLOR CODING OF WARNINGS

1. Color coding of warnings is preferred since colors are better visually discriminated than form, size and brightness differences.

2. For pilot and warning lights specify the following colors:

- a. *Green* to indicate operation or satisfactory conditions.
- b. *Red* to indicate inoperative units, unsatisfactory or hazardous condition.

Use red warning lights for conditions which require immediate action.

- c. *Amber* or yellow to indicate condition not unsatisfactory in itself, but indicative of an impending unsatisfactory or hazardous condition.

Use amber warning lights for conditions which require alertness and caution.

- d. *White* in the same way as green if desired to restrict green lights to power indicator lamps.

Avoid white under night vision conditions.

3. Recommended colors for various items of ground support equipment are given in MIL-S-8512.

4. In color coding, give the fewest possible number of meanings to each color.

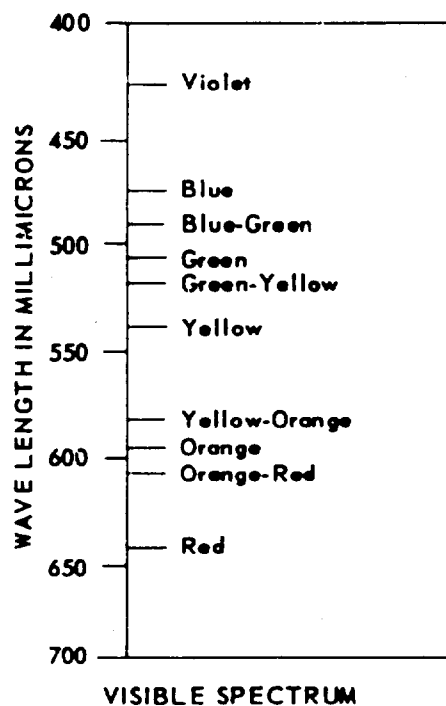
- a. The meaning of a particular color should be consistent throughout a prime equipment.
- b. When color coding equipment, make the pattern consistent with regard to function. Use the same color coding for various components of a unit, for various units of a subsystem and for various sub-systems of a system.
- c. The meaning of colors should be explicitly stated on a panel of the equipment having the color coding when any confusion might arise.
- d. Approximately 11 or 12 colors (including black and white) are clearly distinguishable in the visible spectrum.

(1) The choice of colors for color coding makes little difference, but no more than 6 to 8 colors should be used at one time.

(2) When immediate discrimination is necessary, use no more than 5 to 6 colors.

e. The most readily distinguished colors, under daylight conditions, in order of recognition are as follows:

- (1) Orange
- (2) Yellow
- (3) Green
- (4) Red
- (5) Blue



CAUTION

Colors seen by reflected light may lose their identity at low levels of illumination or under colored lighting conditions.



CHAPTER III

LABELS AND INSTRUCTIONS

- A. TYPES OF LABELS AND INSTRUCTIONS**
- B. PLACEMENT OF LABELS**
- C. LETTERING OF LABELS**

A. TYPES OF LABELS AND INSTRUCTIONS

1. All units and parts should be labeled with full identifying information.
 - a. Each item of equipment should be identified with a securely attached name plate permanently and legibly marked with information specified in MIL-S-8512.
 - b. Clearly label on components or equipment whether they are to be used with AC or DC electricity.
2. Label each test point as follows:
 - a. Give in-tolerance signal.
 - b. Indicate which unit's output is available at that point.
 - c. Mark test points by color.
 - d. Use luminescent markings in low illumination levels.
3. Label each access as follows:
 - a. List items accessible through the access.
 - b. List auxiliary equipment to be used at the access.
 - c. Use some symbol to avoid confusion of that access with other accesses and to permit reference in manuals.
4. Labels should be brief but adequately explanatory.
 - a. Use brief, familiar wording for labels.

Use abbreviations only if they are meaningful and familiar to operating personnel.
 - b. Avoid irrelevance. Emphasize the activity to be performed or the situation to be avoided.
 - c. Labels should read horizontally, not vertically.
5. Markings on plated or unpainted surfaces should be made by embossing, stamping, engraving, or by the use of suitable plates in preference to surface labels such as stenciling, ink stamping or decals.
 - a. For best legibility of labels, the plates should have a dull surface.
 - b. If surface labels must be used, decals or stamped labels are preferable to stenciled labels.
6. Color contrast between letter and plate should be maximum.
 - a. Black lettering on a white background is preferable.
7. Make operating instructions complete and detailed, but job relevant. Note each operation explicitly.



a. Keep language simple. Avoid terms unfamiliar to personnel who will use the written material.

(1) Make emergency instructions as brief and unambiguous as possible.

(2) Sacrifice complete sentences for key action words. Use only common abbreviations.

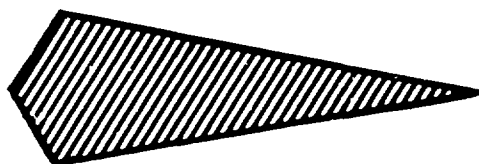
b. For speed of reading and comprehension, use the spaced unit style of typography. Spaced unit is superior to square span, which is superior to standard styles.

THIS IS AN	EXAMPLE OF THE	SPACED UNIT STYLE	OF TYPOGRAPHY
THIS IS AN EXAMPLE		OF THE SQUARE SPAN	STYLE OF TYPOGRAPHY
THIS IS AN EXAMPLE OF THE STANDARD STYLE OF TYPOGRAPHY			

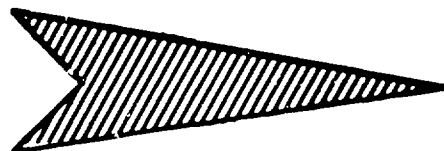
8. Printing on glazed paper should be restricted to a minimum.

9. Use the top two arrows in preference to the lower two arrows for recognition at a distance.

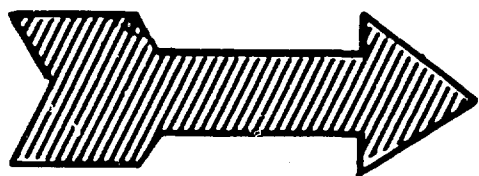
USE



OR



IN PREFERENCE TO



OR

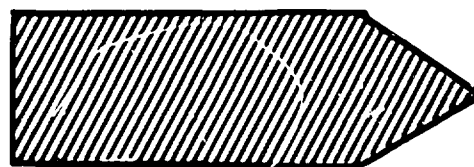


Figure 19

B. PLACEMENT OF LABELS

1. Position labels so they do not crowd or obscure other useful information and so they are not askew or upside down.

a. All numbers should appear in an upright position.

b. Labels on similar pieces of equipment should be in the same relative position.

Labels should not be hidden by units and parts. For example, labels on the chassis should not be placed under the parts which they identify.

- c. Place instructions so that they are visible to the operator from his normal position.

Maximum viewing distance for labels should be 28 inches.

- 2. For easy identification and use, label each test point adjacent to the test point.
- 3. Label on each access cover the symbol designation of the access.

- a. Place adjacent to the access all identifying labels.

If not feasible to present required information in 3 to 4 lines adjacent to the access, present it in job instructions and identify by the symbol designation labeled adjacent to the access and on the access cover.

C. LETTERING OF LABELS

- 1. The visibility of numerals and letters printed in various color combinations depends primarily on brightness and contrast, rather than on color.

- a. In terms of color of print and background, black on white yields the fastest reading time. Green on white, blue on white, and black on yellow are almost as good. The variations result from differences in brightness contrast; those color combinations having no adverse effect on speed of reading are those which have a maximum brightness contrast.

- b. The safest rule to follow is the use of dark ink on a light background.

- c. For ordinary reading material, black on white is preferred. This also holds true for copy to be read at a distance.

- (1). If numerals are used on equipment where the illumination level is 30-50 foot-candles, black numerals on a white background are preferred.

- (2). If numerals are used on equipment where the illumination level is on the order of 10 foot candles, white numerals on a black background are preferred.

- 2. Under low red illumination, characteristics of type (stroke-width, letter-width, and spacing) are more important than under normal illumination, because of the difficulty in recognition. (Fig. 20 illustrates type characteristics)

- a. Under low red illumination, capitals are more easily read than lower case.

- b. Under low red illumination, letters of regular width (capitals: 86% of height, lower case: 90% of loop height) are more easily read than condensed letter-width (capitals: 59% of height, lower case: 71% of loop height).

- c. Under low red illumination, optimum stroke-width is about 25% of mean letter-width.

- d. Under low red illumination, optimum spacing is 50% of mean letter-width.

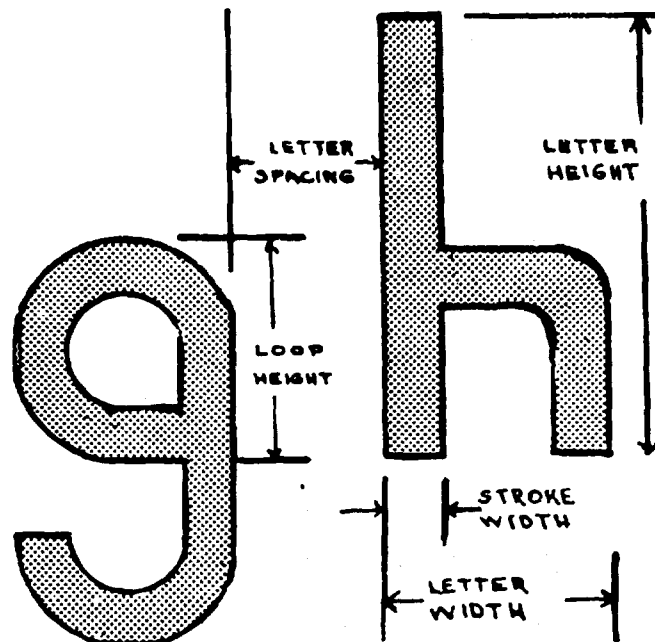


Figure 20

3. Avoid luminous paint for labeling for the following reasons:

- a. Brightness cannot be controlled.
- b. The brightness of paint decreases with time.
- c. Luminous paint cannot be used successfully for fine markings, where markings are less than 1/16 inch in width.

4. Type faces in common use do not differ greatly with respect to the speed with which they are read.

- a. Use of LeRoy lettering guide or Army-Navy Standard AND 10400 styles for lettering or numerals is recommended for labels.
- b. Bold-face type is recommended for material to be read at a distance.
- c. Emphasize certain parts of letters and numerals to make them easier to read.

Optimum numeral shape:

- (1) Make angle at base of the 2 and the 7 and in the tails of the 6 and 9 as near 45 degrees as possible. (See Fig. 21)
- (2) Close angle at the top of the 4.
- (3) Run bar on the 5 over the entire number.
- (4) Make center-point on the 3 fall midway between right and left borders of the figure.

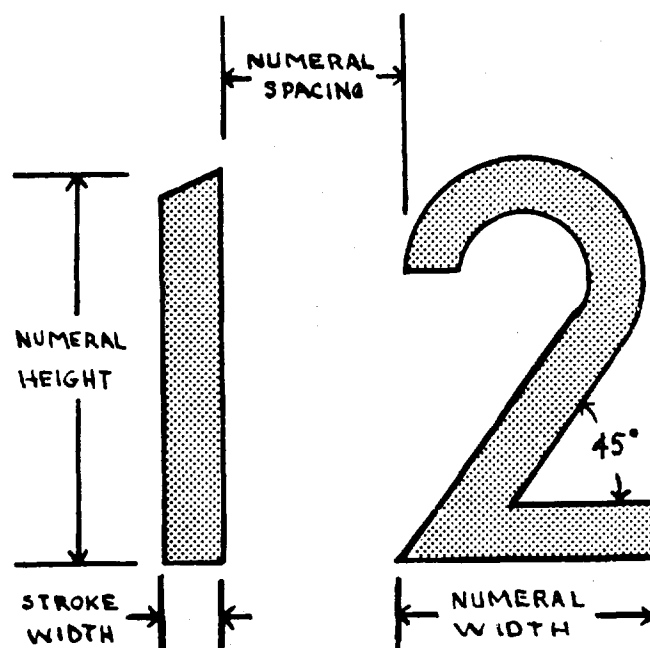


Figure 21

5. The letters which are easiest to read and discriminate are: A, E, N, H, I, J, K, L, T, U, V, X, Y, Z.

Capital letters B and D; C, G and Q; M and W are easily confused.

6. The order of legibility of numbers from best to worst is: 1, 7, 0, 4, 3, 2, 9, 6, 5, 8.

The numerals 6, 8 and 9 are easily confused with one another.

7. When letters are used and the background area is limited, make the letters as large as possible, leaving a margin at least as wide as the stroke-width of the letters to permit discrimination at a maximum distance.

a. Printed material, such as instructions, without any margin at all is read just as rapidly as material having the usual large margin.

b. Margins at the top, outer and bottom of page should not be more than 0.5 inch. Larger margins are no assistance to legibility and they waste space. Inner margins should be large enough so printed matter does not become hidden in the contours of the page entering the binding.

c. Instructions should be printed in double-column composition with very slight margins. When material is printed in two columns, a one-half pica space is recommended between columns. Readers, however, prefer a rule with one-half pica space on each side.

8. Use matte paper in preference to glazed paper. Avoid thin transparent paper.

9. Letter-width: letter-height ratio should be approximately 3:5.

a. Width of letters should be $\frac{3}{5}$ letter-height except for I ($\frac{1}{5}$ - $\frac{1}{7}$ letter-height or one stroke-width) and M, W (20% wider than other letters).



b. Width of numerals should be $\frac{3}{5}$ of their height except for the 4 (approximately $\frac{5}{6}$ numeral-height or one stroke-width wider) and the number 1 ($\frac{1}{6}$ - $\frac{1}{8}$ numeral-height or one stroke-width).

c. Dark letters or numerals on light background should be $\frac{2}{3}$ as wide as high. Stroke-width should be $\frac{1}{6}$ height.

10. In using letters, make stroke-width: letter-height ratio between 1:5 - 1:7.

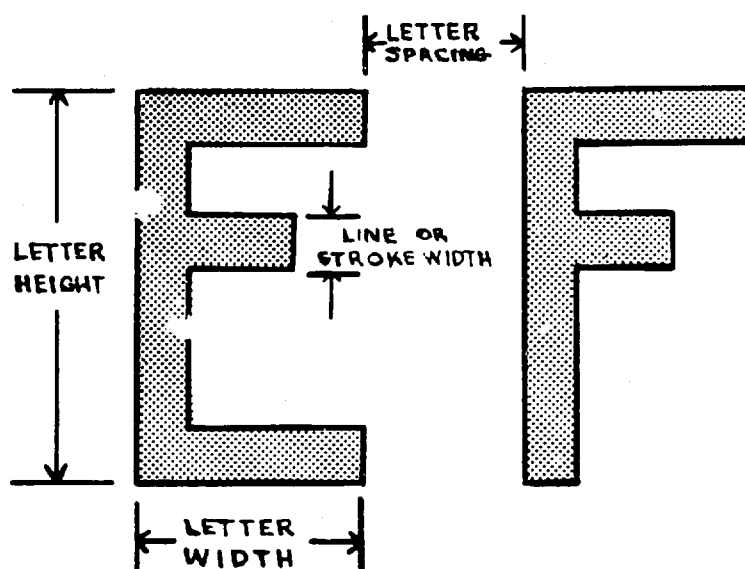


Figure 22

a. In lettering, 1:5 and 1:6 ratios of stroke-width to letter-height are superior to 1:8 and 1:10.

b. In LeRoy lettering style, recommended ratio of stroke-width to numeral-height is 1:6.

c. Stroke-width: numeral-height ratio for numerals should be between 1:6 and 1:8.

d. Make lines used to frame numerals the same stroke width as the numerals used.

11. Height of letters should be at least $\frac{1}{10}$ inch. A letter height of $\frac{1}{4}$ inch is adequate under practically all conditions.

12. For material to be read at ordinary reading distances (approximately 14 inches), use 11 point type.

Letter-height is measured in "points": 1 point = 0.0138 inches.

13. The larger the type the less the importance of line length and leading as factors in legibility.

Leading (spacing between lines) is measured in "points."

14. Make line of reading a medium length (19 picas) for speed in reading.

a. Line length is measured in "picas": 1 pica = 0.166 inches.

b. Excessively long (43 picas) or excessively short (9 picas) lines are read much slower than moderately long lines (19 picas).

RELATIONSHIP OF NUMERAL HEIGHT AND READING DISTANCE

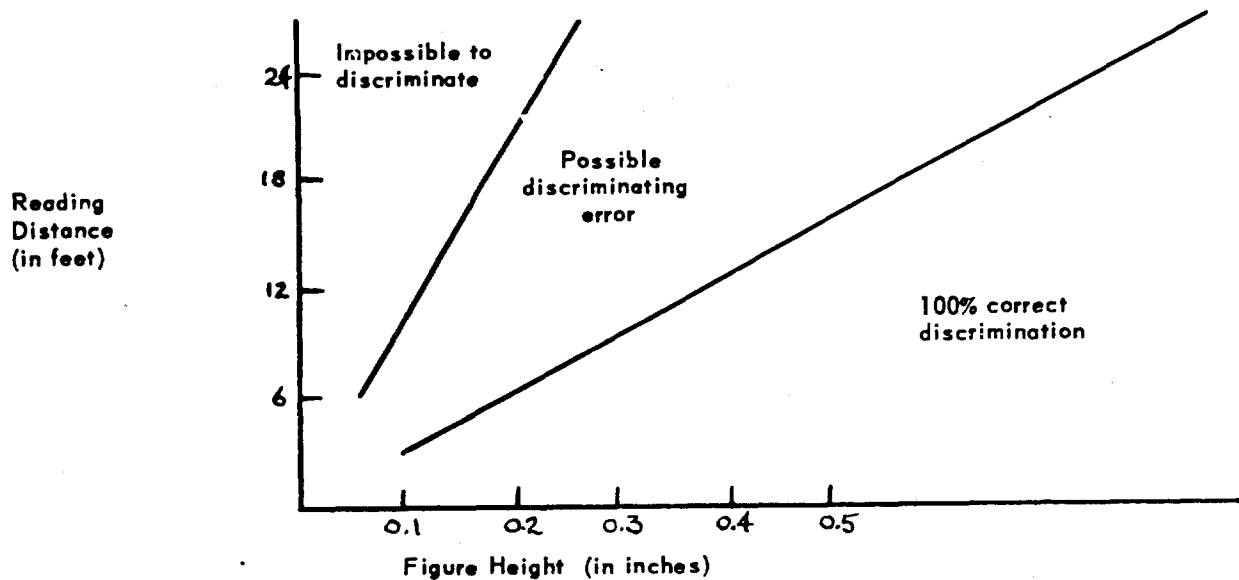


Figure 23

15. For words to be seen at a maximum distance, place the letters in capitals and space the letters as far apart as the average width of the letters being used.

16. Under low red illumination, optimum letter spacing is 50% of mean letter-width.

17. Use lower case lettering with initial caps for long messages where speed of reading is important.

a. Avoid long passages all in caps. For emphasis (short passages) use all caps, bold-face, or italics.

b. Do not print material in all capitals where speed of perception is essential.

18. Labels should be in capital letters; extended copy in lower case.



CHAPTER IV

WORK PLACES

- A. GENERAL CONSIDERATIONS**
- B. STORAGE AREAS**
- C. ILLUMINATION**
- D. SOUND**

A. GENERAL CONSIDERATIONS

1. In designing protective and storage equipment, use maximum body dimensions for openings, foot room, seating widths, knee room and headgear sizes. (See Table 5, page 36)
2. Use minimum body dimensions for reach limits, seating limits, swing limits, and overhead controls and indicators. (See Table 5, page 36)
3. Make the work surface height 42 inches above the floor for tasks requiring an operator to perform a manipulative task while standing.

a. For the standing operator the formula for determination of optimum work surface height is:

$$\text{Work Surface Height} = \text{HH} + 0.50(\text{AL})$$

HH = hand height (distance from finger tip to floor with arm and hand perpendicular to the floor.)

AL = arm length.

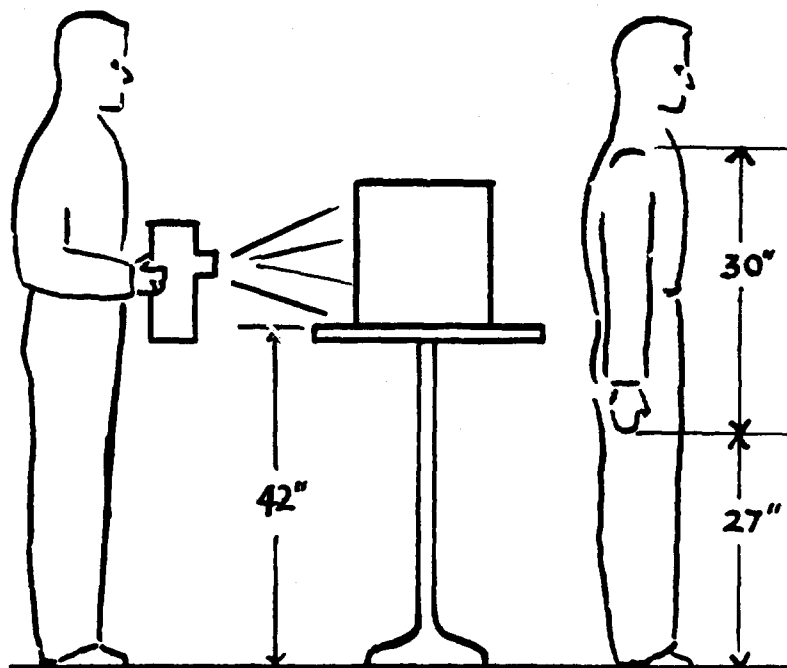


Figure 24

- b. Principal working area for the standing operator should be approximately at elbow height and close to the body.
- c. If design cannot be made to suit each individual, adjust height to the tallest and adjust reach to the smallest individuals who are likely to operate it.

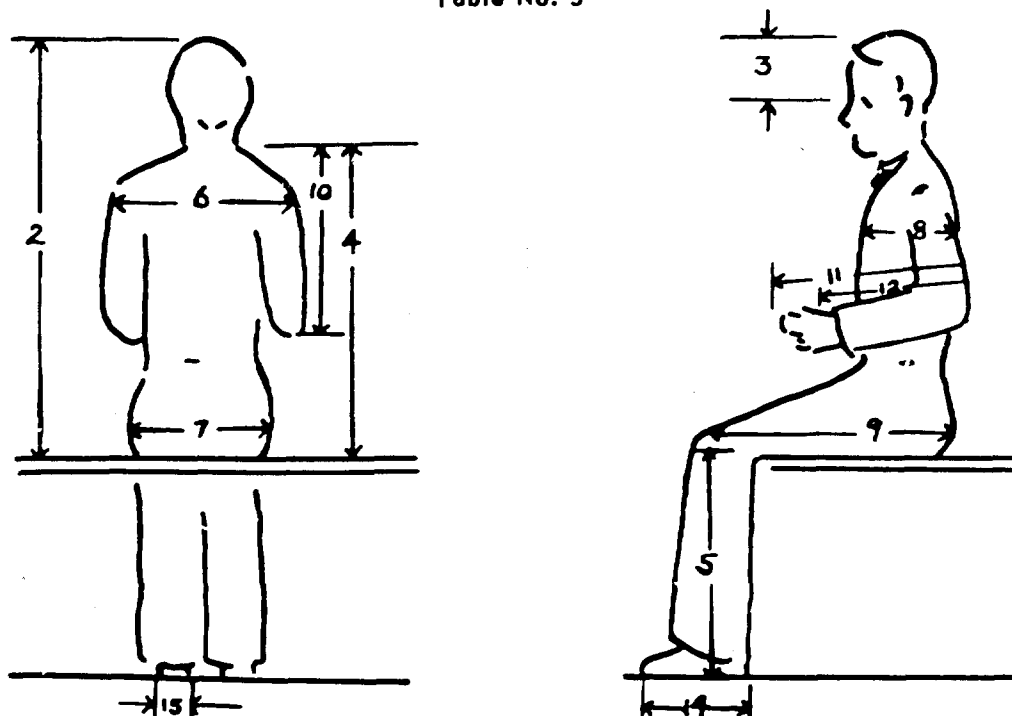
4. Use electromechanical or electrochemical sensing devices rather than humans to detect variations in temperature, small quantities of gas, smoke, toxic substances or radioactivity.

Allow no chemical materials or substances that exceed threshold limit value when inhaled.

Table No. 4 THRESHOLD LIMIT VALUES	
<i>Gases and Vapors</i>	<i>Parts per Million</i>
Acetone	1000
Ammonia	100
Amyl Alcohol	100
Benzene (benzol)	35
Carbon Dioxide	5000
Carbon Monoxide	100
Carbon Tetrachloride	25
Chlorine	1
O-Dichlorobenzene	50
Ethyl Alcohol (ethanol)	1000
Fluorine	0.1
Gasoline	500
Hydrogen Chloride	5
Hydrogen Sulfide	20
Methyl Alcohol (methanol)	200
Naphtha (coal tar)	200
Naphtha (petroleum)	500
Ozone	0.1
Phosphine	0.05
Propyl Alcohol (isopropyl alcohol)	400
Turpentine	100
* For additional allowable concentrations see U.S.A.F. pamphlet AFP 160-6-1, Threshold Limit Values for Toxic Chemicals.	

5. When equipment may involve exposure of personnel to corrosive agents, provide for operation with protective clothing. Make equipment as automatic as possible. (Remote controls, closed circuit venting, automatic closure on pipes and hoses.)

Table No. 5



HUMAN MEASUREMENTS *					
No.		Median	Range		90% Range
			Min.	Max.	
1	Standing Height (without shoes)	69.2	61.4	78.0	65.4-73.1
2	Sitting Height	36.1	31.3	40.8	34.3-38.5
3	Eye Height (head top to pupil center)	4.4	3.4	5.7	3.9- 5.1
4	Shoulder Height	24.5	20.2	28.7	22.7-26.5
5	Knee Height (without shoes)	22.0	18.1	25.6	20.4-23.6
6	Bi-Deltoid (across shoulders)	18.0	15.4	20.5	16.7-19.3
7	Bi-Trochanteric (across buttocks)	14.0	11.8	18.5	13.1-15.5
8	Chest - Thickness	9.6	7.9	12.3	8.6-10.8
9	Thigh Length	23.6	19.3	27.6	22.0-25.6
10	Shoulder - Elbow Length	14.7	10.6	16.9	13.6-15.8
11	Elbow to Fingertip Length	18.7	16.7	21.8	17.5-20.5
12	Elbow to Center of Grip, Length	14.1	12.4	16.4	13.0-15.5
13	Hand Length	7.6	6.4	8.8	7.1- 8.2
14	G.I. Shoe Length	11.7	10.1	13.5	11.0-12.6
15	G.I. Shoe Width	4.2	3.7	4.6	3.9- 4.4
16	Foot Length	10.5	8.8	12.2	9.6-11.3
17	Foot Width	3.9	3.1	4.6	3.6--4.2
18	Bi-Iliac Width (across hipbones)	11.4	9.1	13.4	10.4-12.4
19	Anterior Arm Reach	35.2	29.5	40.6	32.7-37.8

* All Measurements in inches



B. STORAGE AREAS

1. Design storage areas so that the stored items used most frequently are the most accessible.

Design storage areas so that frequently used items are transported as short a distance as possible.

2. The type of storage area should be compatible with the kind of material being stored.
 - a. Electrical equipment storage areas should be designed so that the units will not be stored in a position which might cause injury to them, i.e., never stack or pile delicate electrical units.
 - b. Storage areas for gasoline and fuel oil, etc., should be in underground tanks, vented to prevent an accumulation of explosive gases.
 - c. Storage areas should be such that metal subject to corrosion is stored in a dry place. (Metal should be coated to prevent oxidation.)
 - d. Storage areas should be designed so that material is kept off the floor or the ground.
 - e. Design storage areas such that material that will not be damaged by weather can be stored in the open or merely under a roof.
3. Insure that storage areas serviced by fork-lift trucks require piling of units no higher than 16 feet. Care should be exercised that lower units are not crushed by the weight of the units stacked above.
4. Use steel shelving for more durable use and when there is possibility of fire hazard.

Use adjustable steel shelving when there is the possibility that the shelving will be added to, moved, or rearranged.
5. Shelving should be designed so that the top shelf is no higher than 76 inches from the floor. The depth of shelving is determined by considering the unit size of its contents, i.e., small units should not be stored on deep shelves.

The maximum height of the next to last layer (or shelf) on which equipment is stored, should be no more than 5 feet above the floor.

6. The dimensions of storage bins should be that of the standard unit or multiples thereof.
 - a. The depth of the bin should be the depth of the standard unit, if space is not to be wasted.
 - b. Design storage areas such that the row width is multiples of the unit being stored. For example, if the unit is 2 feet square, a row may be 16 feet or 24 feet long, but should not be 15 or 23 feet long. The shelf should be 2 feet deep and 2 feet high.
 - c. If the unit being stored is rectangular, the storage area should be such that the short dimension of the unit is parallel to the length of the row, and the long dimension perpendicular to it in order to obtain the maximum ratio of bin or storage area to aisle area.

7. Main aisles should run lengthwise in the storeroom. Main aisles should be wide enough for two-way passing of trucks and other transportation equipment. Such aisles should be generally 6 to 10 feet wide depending upon traffic conditions.

a. Sub-aisles should be laid out parallel to the main aisle and should be wide enough for trucks to be turned around while working in them. These aisles should be from 15 to 25 feet from the main aisle and from 5 to 6 feet wide.

b. Cross aisles should be perpendicular to the main aisle and should be 5 feet in width to accommodate one-way traffic and to provide sufficient space for loading and unloading. Where units are carried by hand, cross aisles should be 3 feet in width. Under no circumstances should the cross aisle be less than 30 inches wide.

8. Minimum distances for aisles used only by humans:

1-man passage -- 20 inches

2-man passage -- 48 to 54 inches.

When a door opens into an aisle, the width of the aisle should be between 5'6" and 6 feet.

When two facing doors open into an aisle, the width of the aisle should be between 7 and 8 feet.

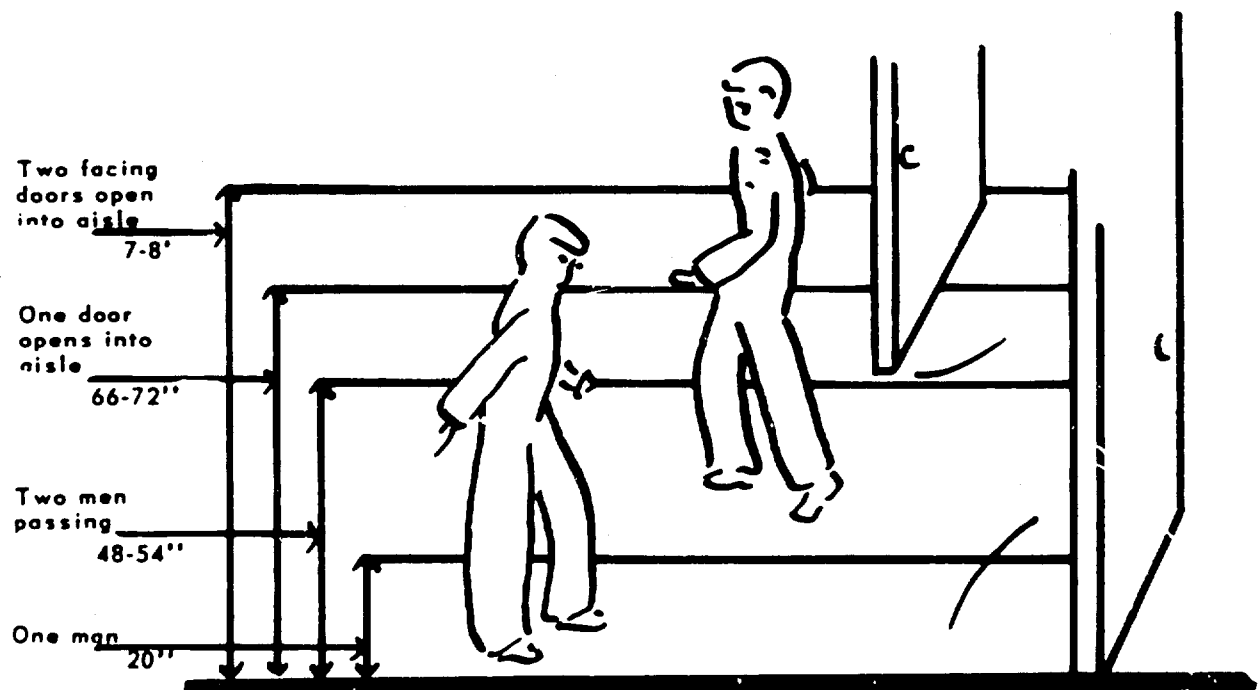


Figure 25

9. Design storage areas so that there is at least a 36 inch aisle between the lower storage shelving and the wall, to provide ample room for removal of items.

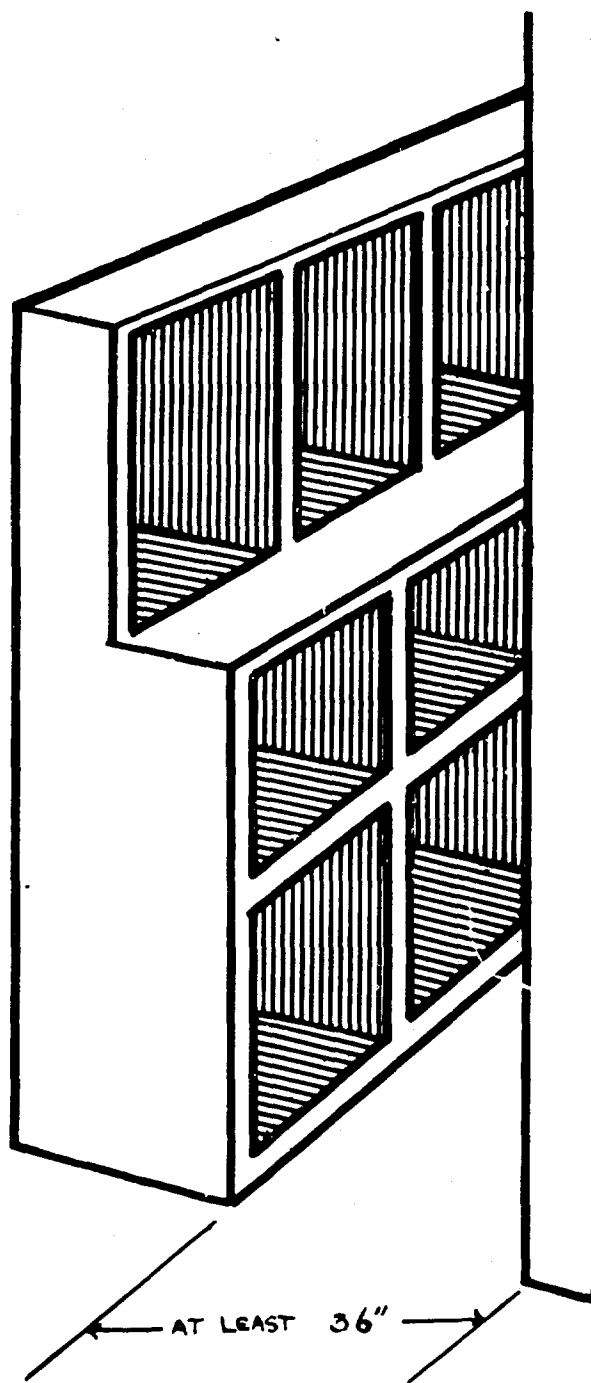


Figure 26

C. ILLUMINATION

1. Provide adequate illumination for each protective and storage work area in terms of type and duration of task to be performed.

Table 6	
RECOMMENDED ILLUMINATION LEVELS	
Task	Illumination in Footcandles
Difficult, prolonged tasks with objects of low brightness contrast.	100+
Drafting, watch repairing, inspection of material, precision machine work.	50+
Sustained reading, object assembly, bench work, general office, lab. work.	25+
Occasional or brief reading, power plants, waiting rooms.	10+
Stairways, supply warehouses.	5+

2. Use diffuse light or matte finishes on flat surfaces to reduce reflection or glare from work surfaces.



D. SOUND

1. When designing equipment to be operated by a team, include features which make for increased possibilities for communication between all members of the team.
 - a. Groups which have opportunity and are permitted maximum communication between team members work faster, send more messages, and are better satisfied with the group than groups in which communication is limited.
 - b. Provide a signal: noise ratio of 4:1 for good communication.
2. In general, keep sound levels below 85 db (reference level 0.0002 dynes per square centimeter) to prevent illness or injury to personnel.

Table 7

MAXIMUM TOLERABLE SOUND LEVELS *

Frequency Band in CPS	Exposure for Less than 1 Hour per Day (Without Communication)	Exposure for 1-8 Hours per Day (Without Communication)	Exposure when Communication Is Required
35-75	115	106	106
75-150	105	96	96
150-300	97	88	88
300-600	94	85	81
600-1200	93	84	75
1200-2400	92	83	72
2400-4800	91	82	71
4800-9600	90	81	69

* Sound Measured in db's (ref. 0.0002 dynes/cm²) at Head Level in Area Where Operator is Located.

Insure Measured Noise Level Not More Than Values Indicated Above.

Table 8

SOUND LIMITATIONS (1000 - 4000 CPS)

- 20 - 50 db - Too soft for easy hearing.
- 50 - 80 db - Comfortable hearing.
- 80 - 120 db - Noticeably uncomfortable (fatigue - irritability).
- 140 db - Produces pain.



SELECTED BIBLIOGRAPHY

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Berkun, M. M. and Van Cott, H. P. *Checklist of human engineering evaluation factors (plans inspection) "CHEEF 1."* Wright Air Development Center, Ohio, WADC (AF-WP-(B)-0-23 Nov. 56 150), September 1956. (American Institute for Research, AIR-24-56-FR-135)

This checklist is intended as an aid in the human engineering evaluation of developmental weapons, sub-systems and support equipment. It is to be used to evaluate human engineering characteristics from drawings, blueprints and other written plans.

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This cleverly illustrated booklet presents many human engineering recommendations on the design of electronic equipment for ease in field maintenance. Included is an expanded human engineering checklist of over 80 design items.

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The most complete bibliography of human engineering sources. It attempts to include only items pertaining to human engineering design, in order "... to place in the hands of design engineers a usable source of human engineering information which can be applied directly to the problems related to the designing of equipment. ..." There are sixteen sections containing 5,666 references.

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A checklist intended as an aid in the human engineering evaluation of developmental weapons, sub-systems, and support equipment. It is to be used to evaluate human engineering characteristics from mockups, prototypes, and other initial pieces of equipment during their design inspection.

Van Cott, H. P. and Altman, J. W. *Procedures for including human engineering factors in the development of weapon systems*. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC TR 56-488, October 1956. (American Institute for Research, AIR-24-56-FR-139)

This volume presents a systematic procedure for insuring that human factors are considered at each appropriate step in the development of weapon systems. Information is given on human capabilities and limitations; and procedures for assessing and solving human engineering problems are suggested.

Woodson, W. E. *Human engineering guide for equipment designers*. University of California Press, Berkeley, 1954.

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Prepared for design engineers, this document sets forth design principles and practices, both general and specific, to be used in designing equipment for maximum operator utilization. The seven sections are entitled: General Requirements, Visual Displays, Controls, Physical Characteristics, Ambient Environment, Work Place Characteristics, and Hazards and Safety.

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